A STUDY OF COBALT 62

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A STUDY OF COBALT 62

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By

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GENERAL INTRODUCTION

The study of artificial radioactivity has led to the development of many different experimental techniques. Conversely, an attempt to develop a new experimental technique, or a new piece of equipment, may well lead an investigator to study an unreported or questionable artificial radioactivity. Such a case has led to the report presented here. In an attempt to develop equipment and a technique for the study of short-lived radioisotopes, a 1.6 minute activity, resulting from the bombardment of nickel foil with deuterons, was observed. A search of the literature disclosed that the classification of this 1.6 minute activity was questionable. A study of this activity was undertaken, therefore, in an effort to verify previously reported experimental results and to properly identify the radiation and the isotope from which it arises.

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A. A Description of Equipment

During the course of this investigation an "outside" probe was used for a majority of the bombardments performed at the Ohio State University cyclotron. The term "outside" is used as this particular probe allows the target sample to be bombarded at atmospheric pressure. Essentially, the sample is outside of the vacuum tank of the cyclotron when this probe is being used.

The probe was originally designed for use in bombarding tissue samples. When an attempt to study short-lived activities was made, it was thought that the outside probe could be modified in such a way as to allow the rapid extraction of the bombarded sample. This modification was easily accomplished, and the outside probe has proved extremely useful.

Described simply, the probe consists of a hollow tube, closed on one end. The closed end of the tube is inserted into the tank of the cyclotron. A very thin (0.0005 inches) copper foil, approximately 3/8" by 1/8" in dimensions, is used as a window in the closed end of the tube. The foil is strong enough to withstand the pressure from the inside of the tube when the probe is inserted into the vacuum system of the cyclotron. The bombarding particles pass from the vacuum tank of the cyclotron to the sample target through this window. Thus the target is bombarded outside of the cyclotron.

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The target itself is fastened to a copper rod that will easily slide in and out of the hollow tube. With such an

arrangement, the target can be removed from the cyclotron beam and placed in a counter in approximately six seconds. Also, the length of bombardment time can be very closely regulated by using this outside probe.

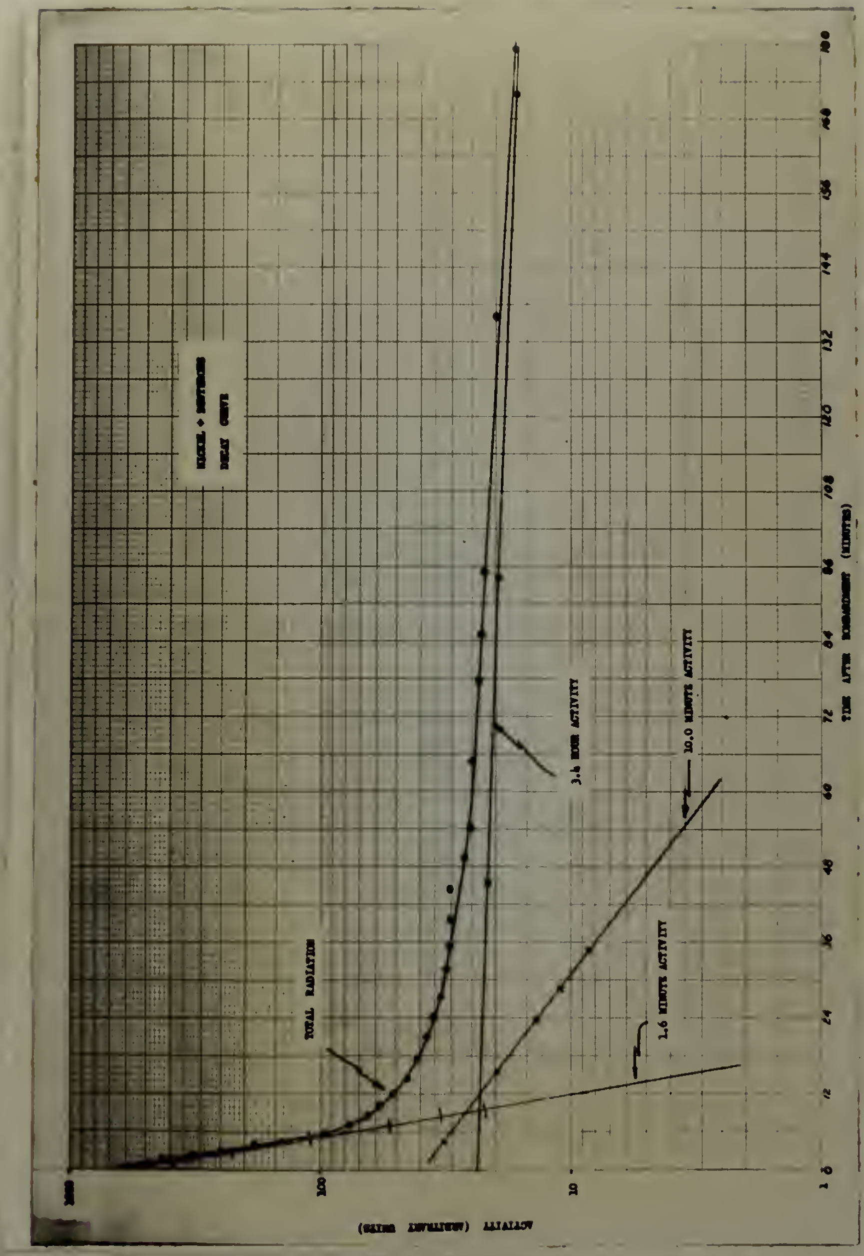
All half-life measurements were made with a positron counter incorporating a Tracerlab "64" Scaler as the scaling circuit. A Geiger-Mueller tube was used as a counter. All absorption measurements were made with the same "64" Scaler and Geiger-Mueller tube, but the magnet of the positron counter was not utilized.

B. Experiments Performed and Results Obtained

The initial experiments were made by bombarding nickel foil with deuterons. The decay of the resultant activity was followed on the positron counter (without utilizing the magnet) and a 1.6 minute activity was found as shown in figure No. 1. The 3.4 hour activity observed was attributed to Cu^{61} and the 10 minute activity was attributed to Cu^{62}.

Further deuteron bombardments were carried out using nickel oxide as the target material. The beta (negatron) activity was followed on the positron counter and a 1.8 minute activity was observed (figure No. 2). The base line of this curve is the 12.9 hour Cu^{64} activity. Subtraction of this base line disclosed the 2.56 hour Ni^{65} activity. Further subtraction showed an 11 minute activity. This was attributed to Co^{60}. A final subtraction revealed the 1.8 minute activity.

Further deuteron bombardments were performed using



TOTAL RADIATION
3.4 HOUR ACTIVITY
10.0 MINUTE ACTIVITY
1.6 MINUTE ACTIVITY
1000
100
10
1
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
180

Figure No. 1

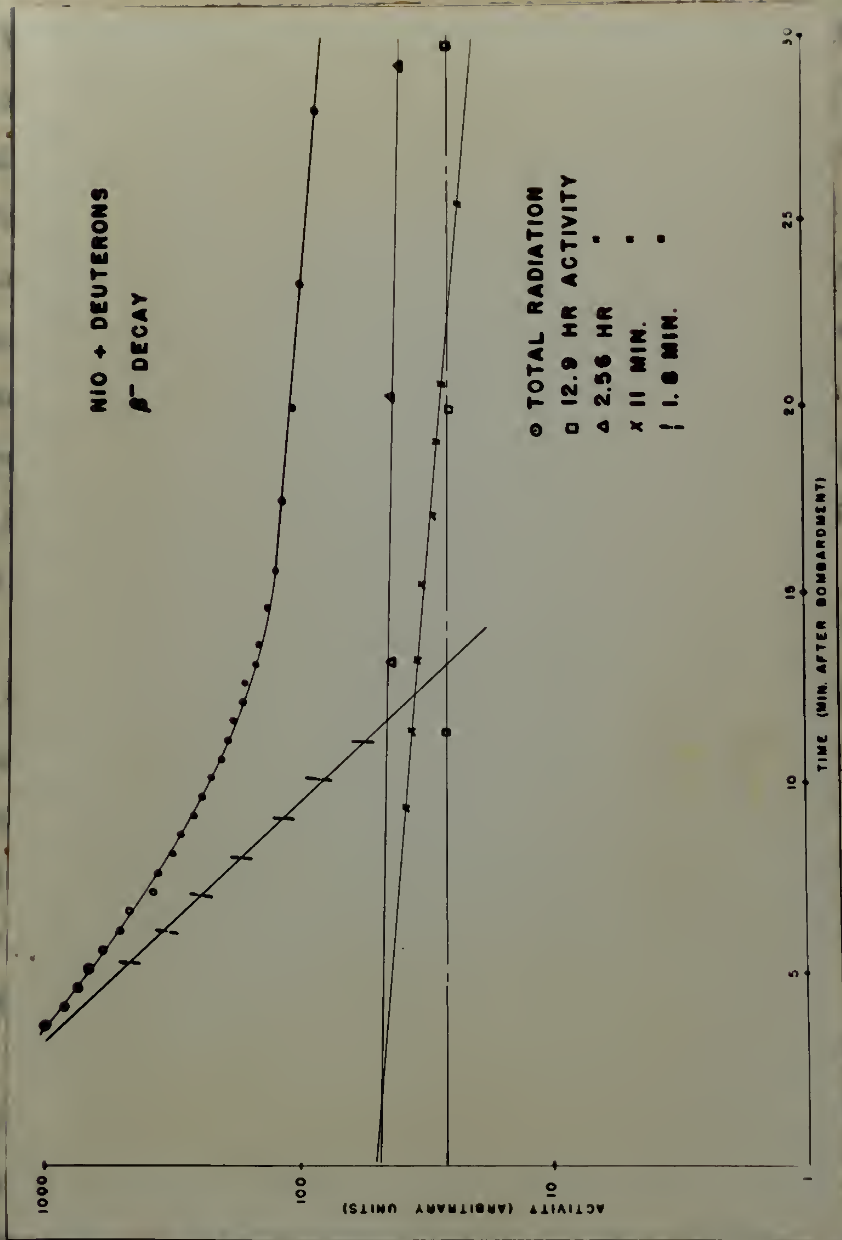

NIO + DEUTERONS
β⁻ DECAY
TOTAL RADIATION
12.9 HR ACTIVITY
2.56 HR
11 MIN.
1.8 MIN.
TIME (MIN. AFTER BOMBARDMENT)
ACTIVITY (ARBITRARY UNITS)
1000
100
10
5
10
15
20
25
30

Figure No. 2

nickel oxide enriched in Ni^{64}. A study of the literature (1) had disclosed that the 1.6 minute activity arose from the deuteron bombardment of this particular nickel isotope. The percentage of Ni^{64} in the enriched sample was 80.6 percent. In naturally occurring nickel, this stable isotope of nickel has a percentage abundance of only 1.16 percent. The enriched sample was obtained from the Stable Isotopes Division, Oak Ridge National Laboratory. After bombardment with deuterons, the beta decay of the resultant activity was again followed on the positron counter. The 1.6 minute activity was disclosed by the graph after subtraction of the 2.6 hour Ni^{65} activity (figure No. 3).

An attempt to prove, from the branching ratios, that the 1.6 minute activity arose only from the deuteron bombardment of Ni^{64} was inconclusive. The NiO and $Ni^{64}O$ were bombarded for only 30 seconds, yet the activity resulting was so great that it was necessary to wait for several minutes before attempting to use the positron counter. Thus, on the graphs, accurate extrapolation to "zero" time could not be made.

Other experiments were then conducted in an effort to classify the isotope giving rise to this 1.6 minute beta activity. Proton bombardments of nickel foil disclosed no 1.6 minute activity. Gamma ray bombardments of nickel foil resulted in no 1.6 minute activity. The gamma rays were obtained by bombarding lithium metal with protons. Neutrons, produced by hitting copper with deuterons, were used to bombard Ni foil and a definite 1.6 minute activity resulted, as shown in figure No. 4. Neutrons, produced by hitting gold with deuterons, were used to

nickel oxide enriched in Ni^{64}. A study of the literature (2) had disclosed that the 1.6 minute activity arose from the neutron bombardment of this particular nickel isotope. The percentage of Ni^{64} in the enriched sample was 60.0 percent. In naturally occurring nickel, this stable isotope of nickel has a percentage abundance of only 1.16 percent. The enriched sample was obtained from the Stable Isotopes Division, Oak Ridge National Laboratory. After bombardment with deuterons, the beta decay of the resultant activity was again followed on the positron counter. The 1.6 minute activity was disclosed by the graph after subtraction of the 2.6 hour Ni^{65} activity (Figure No. 3).

An attempt to prove, from the bombarding results, that the 1.6 minute activity arose only from the deuteron bombardment of Ni^{64} was inconclusive. The NiO and $Ni^{64}O$ were bombarded for only 30 seconds, yet the activity remaining was so great that it was necessary to wait for several minutes before attempting to use the positron counter. Thus, on the graphs, accurate extrapolation to "zero" time could not be made.

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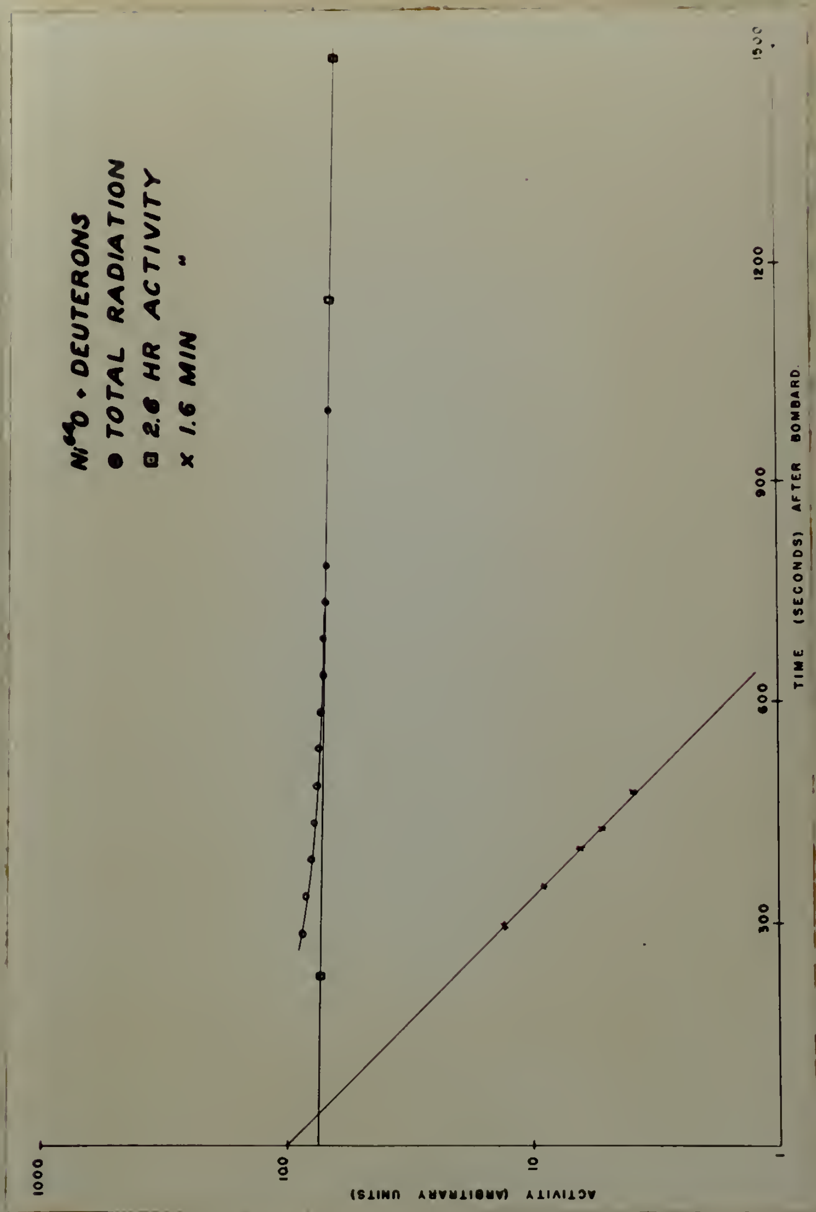

DEUTERONS
TOTAL RADIATION
2.6 HR ACTIVITY
1.6 MIN
TIME (SECONDS) AFTER BOMBARD.
ACTIVITY (ARBITRARY UNITS)
1000
100
10
1
300
600
900
1200
1500

Figure No. 3

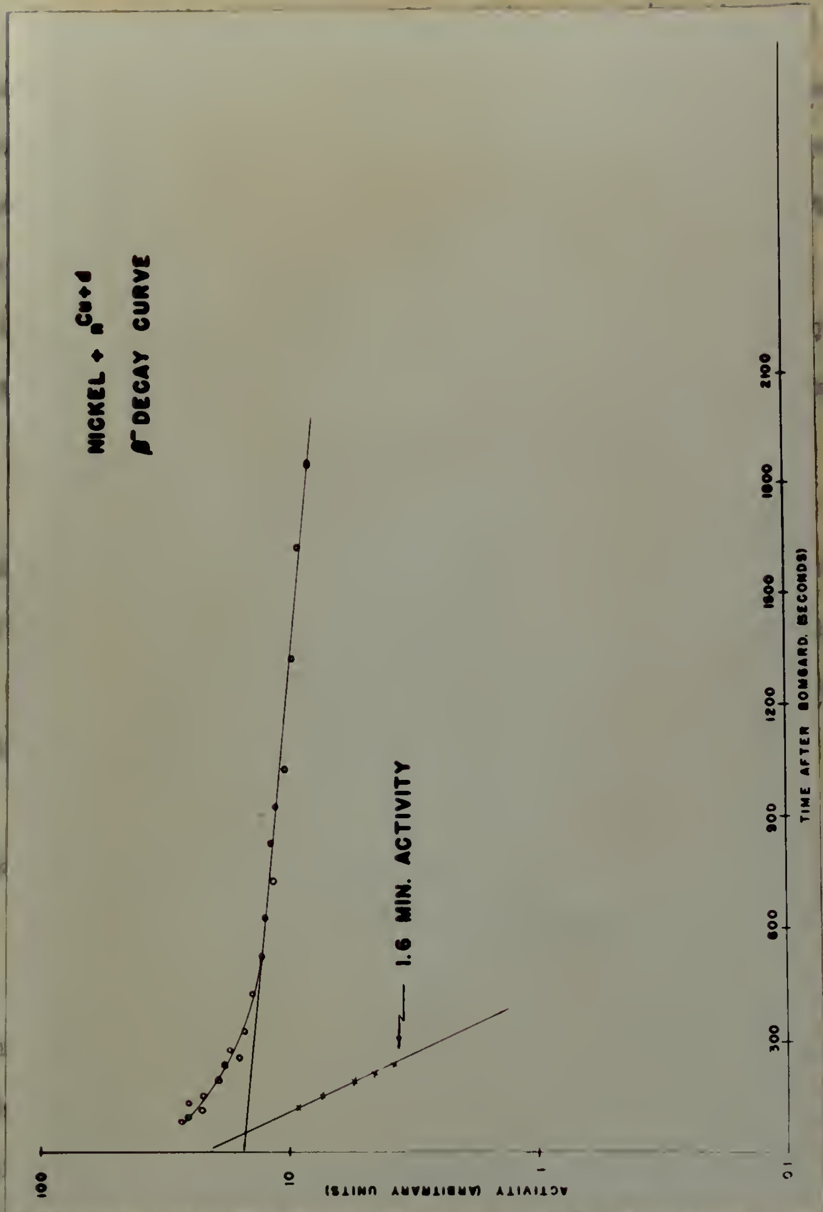

NICKEL + n Cu+d
β⁻ DECAY CURVE
1.6 MIN. ACTIVITY
TIME AFTER BOMBARD. (SECONDS)
ACTIVITY (ARBITRARY UNITS)
100
10
1
0.1
300
600
900
1200
1500
1800
2100

Figure No. 4

Figure No. 4

bombard the $Ni^{64}O$. No 1.6 minute activity resulted (figure No. 5).

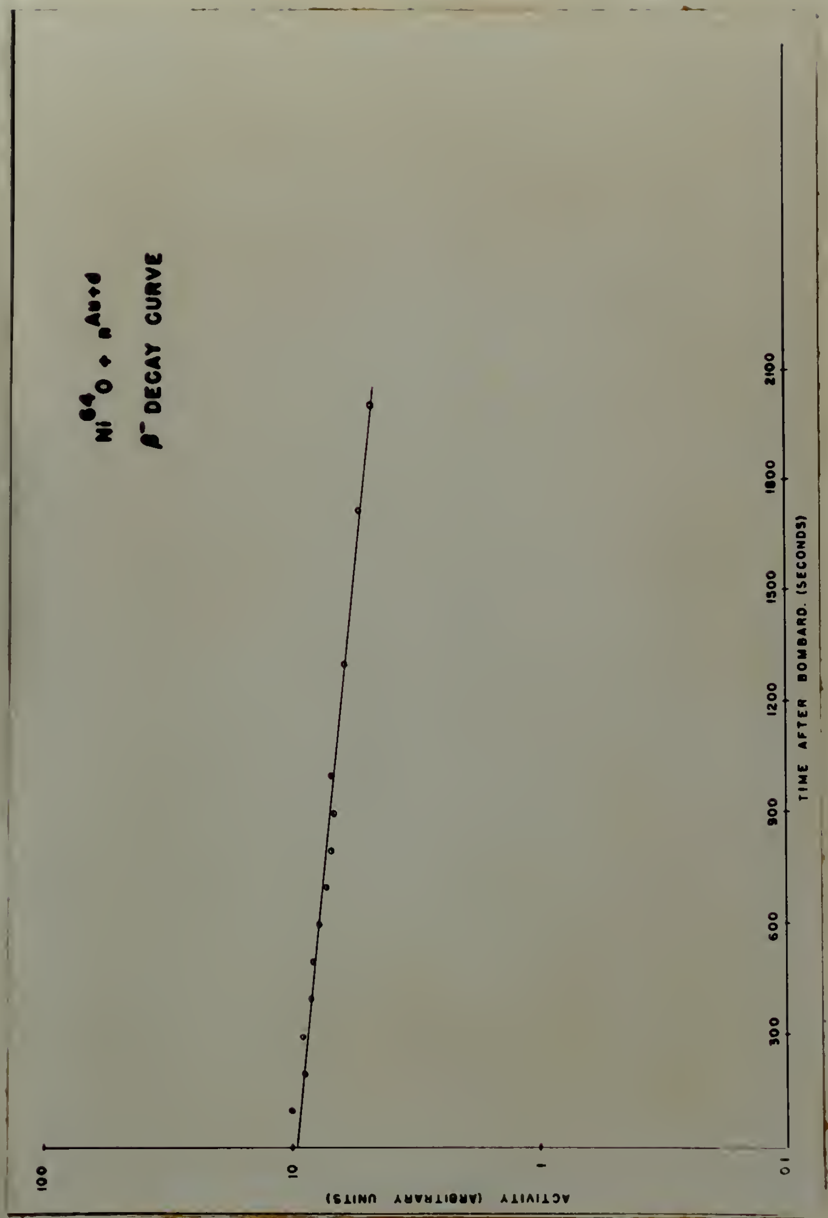
Several other experiments were conducted by bombarding nickel foil with deuterons for a period of five seconds. Aluminum absorption measurements were made in an effort to determine the beta end point energy of the 1.6 minute activity. The end point was determined as 1550 milligrams of aluminum absorber, plus or minus 50 milligrams. The absorption measurements were all taken during a time interval in which the sample was decaying on a 1.6 minute half life, and each absorption measurement was corrected for the decay of the sample (figure No. 6).

During the course of several of the experiments it was noticed, from sample background measurements on the positron counter, that a short-lived gamma activity accompanied the 1.6 minute beta activity. Half life determinations of the gamma activity showed a period of approximately 1.9 minutes.

C. Results Reported Previously

A study of the literature (1) revealed that the 1.6 minute activity, both beta and gamma, had been observed to arise from the fast neutron bombardment of Ni^{62} as well as the deuteron bombardment of Ni^{64}. The neutron bombardment also revealed a 13.9 minute beta and gamma activity. Chemical separation showed the 13.9 minute activity to be in the cobalt fraction. The investigators assigned the 13.9 minute activity to cobalt 62. The basis for the assignment is as follows:

"The fact that nothing shorter than the 1.75 hour cobalt 61 appeared in the cobalt from nickel 61 is significant



β^- DECAY CURVE
ACTIVITY (ARBITRARY UNITS)
TIME AFTER BOMBARD. (SECONDS)
100
10
1
0.1
300
600
900
1200
1500
1800
2100

Figure No. 5

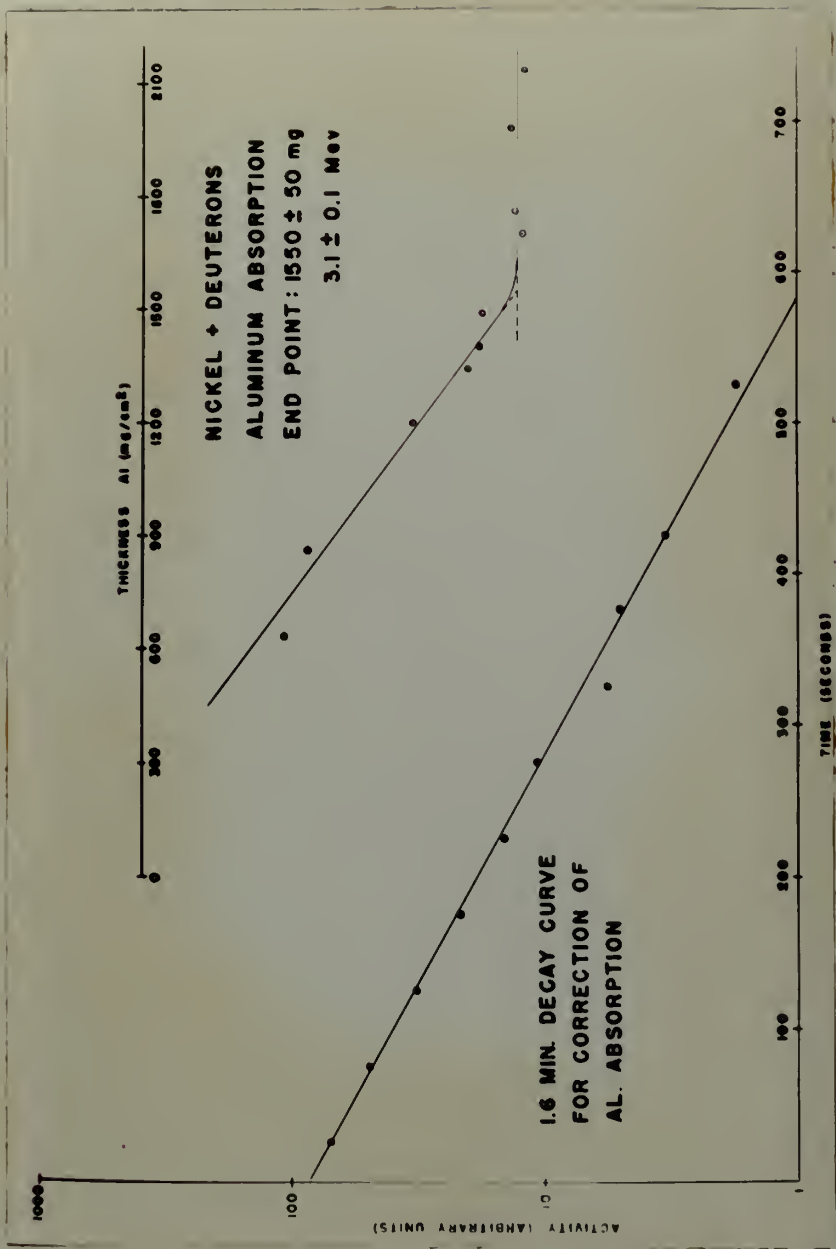

NICKEL + DEUTERONS
ALUMINUM ABSORPTION
END POINT: 1550 ± 50 mg
3.1 ± 0.1 Mev
1.6 MIN. DECAY CURVE
FOR CORRECTION OF
AL. ABSORPTION
THICKNESS Al (mg/cm²)
TIME (SECONDS)
ACTIVITY (ARBITRARY UNITS)

Figure No. 6

since an (n,pn) reaction should yield Co^{60} which has a 10.7 minute activity. Inasmuch as this activity does not appear in the Ni^{61} sample it implies that the yield of (n,pn) reactions here is probably negligible. These facts make it apparent that the 13.9 minute decay is associated with an (n,p) reaction in Ni^{62} yielding Co^{62}." The quotation has been taken from the published report.

The 1.75 hour activity mentioned above resulted from the neutron bombardment of Ni^{61} and has been definitely established as arising from Co^{61}. Both chemical and mass separations were performed in order to positively assign this activity.

The investigators tentatively assigned the 1.6 minute activity to Co^{62}. It was thought to be isomeric with the 13.9 minute activity since it also arose from the fast neutron bombardment of Ni^{62}. The 1.6 minute activity was thought to result from a (d,alpha) reaction when the Ni^{64} was bombarded with deuterons.

D. Conclusions

On the basis of the experimental results obtained at the Ohio State University cyclotron, it is felt that the following conclusions can be made:

1. The 1.6 minute activity probably arises from Co^{62} produced by a (d,alpha) reaction in Ni^{64}. The activity appeared from all deuteron bombardments of nickel foil, nickel oxide, and enriched nickel 64. The 1.6 minute activity also resulted from the neutron bombardment of nickel foil, probably due to a (n,p) reaction on the nickel 62 present in the nickel foil. The fact that the activity did not arise from the proton bombardment of

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nickel tends to preclude the assignment of the activity to a copper isotope. The results of the gamma bombardment of nickel foil, and the neutron bombardment of $Ni^{64}O$ tend to preclude the assignment of the activity to a nickel isotope.

2. Co^{62} decays by emitting a 3.1 Mev beta particle and a gamma ray of undetermined energy. The half life of this radioactive isotope is 1.6 minutes.

3. The 13.9 minute beta and gamma activity previously reported (1) is not isomeric with the 1.6 minute Co^{62} activity. It is possible that this 13.9 minute activity belongs to some other cobalt isotope. This conclusion is based on energy considerations. The reported energy (1) of the beta particle associated with this 13.9 minute activity is 2.3 Mev. The observed energy of the beta particle associated with the 1.6 minute activity is 3.1 Mev. Thus, any deuteron beam capable of producing the 1.6 minute activity must also produce the 13.9 minute activity if the two activities are isomeric. Since the 13.9 minute activity was never observed to arise from any of the deuteron bombardments performed by this investigator, it is felt that the 13.9 minute activity is not isomeric with the 1.6 minute activity and should not, therefore, be assigned to Co^{62}.

Further work is apparently necessary to clarify the assignment of the 13.9 minute activity. The experimental results obtained by this investigator are not in agreement with the results obtained by others. For the present, it is suggested that the classification of this 13.9 minute activity be considered doubtful until further experimental data is collected.

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